11.—Metamict allanite from pegmatites cutting basic charnockitic granulites in the Fraser Range, Western Australia

by Allan F. Wilson*

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Abstract

A metamict allanite from a muscovite pegmatite which cuts pyroxene granulites is chemically similar to normal allanites in most respects. However, MgO (1.96%) and Al_2O_3 (17.20%) are slightly more abundant than normal, whereas ThO_2 (0.79%) and H_2O+ (1.08%) are slightly lower. Values for U, Th and Pb indicate an age of 1210 m.y., which is thus a minimum age for the granulites of the Fraser Range. This age is similar to that determined by using Rb/Sr and K/A techniques on muscovite from the allanite-bearing pegmatite.

Small black masses of isotropic "hydroallanite" were found by a prospector near Newman Rock, east of the Fraser Range, in 1908. In 1934 another prospector from a similar area submitted to Dr. E. S. Simpson several pounds of brownish black vitreous material, which on examination was found to be an isotropic "hydroallanite".

An analysis of a "hydroallanite" from the Fraser Range is given by Simpson (1948 p. 30); see Table 1 (actually a normal allanite). The precise locality is not stated. However, the chemical analysis of the sample is very similar to the new allanite described below, and may well come from the same pegmatite.

In 1952 I collected several pounds of metamict allanite from a number of pegmatites about 300 yards south of the Eyre Highway near the 73 mile-post from Norseman. Allanite for analysis was taken from a shallow prospecting pit dug for either muscovite or allanite. Weathered fragments of allanite (up to 10 cm x 4 cm x 3 cm) have been found on the surface near adjacent pegmatites.

The areal distribution of the allanite-bearing pegmatites is shown in Figure 1. The strike of the main pegmatite is about 27°. The dip of the pegmatite was not observed as no good contacts with the country rock were found. However, from topographic considerations it is likely to be steeply dipping.

The country rocks are dominantly basic granulites of charnockitic type, which are cut by metagabbro dykes (Wilson 1965). The regional trend of the granulites is shown in Figure 1.

The dominant mineral aggregate is a very handsome coarse microcline-quartz graphic intergrowth which is commonly 30 cm in diameter and up to 2 metres in diameter. Quartz, which tends to form an ill-defined core is commonly a dark smoky variety, especially in the vicinity of the pit where allanite occurs. Muscovite, which looks dark in hand specimen, and biotite occur patchily throughout most of the pegmatites. Black tourmaline and magnetite are other important accessory minerals. A geiger counter was used (without success) to try to locate hidden pockets of allanite or other radioactive minerals. Zoning in the pegmatite was not studied in detail.

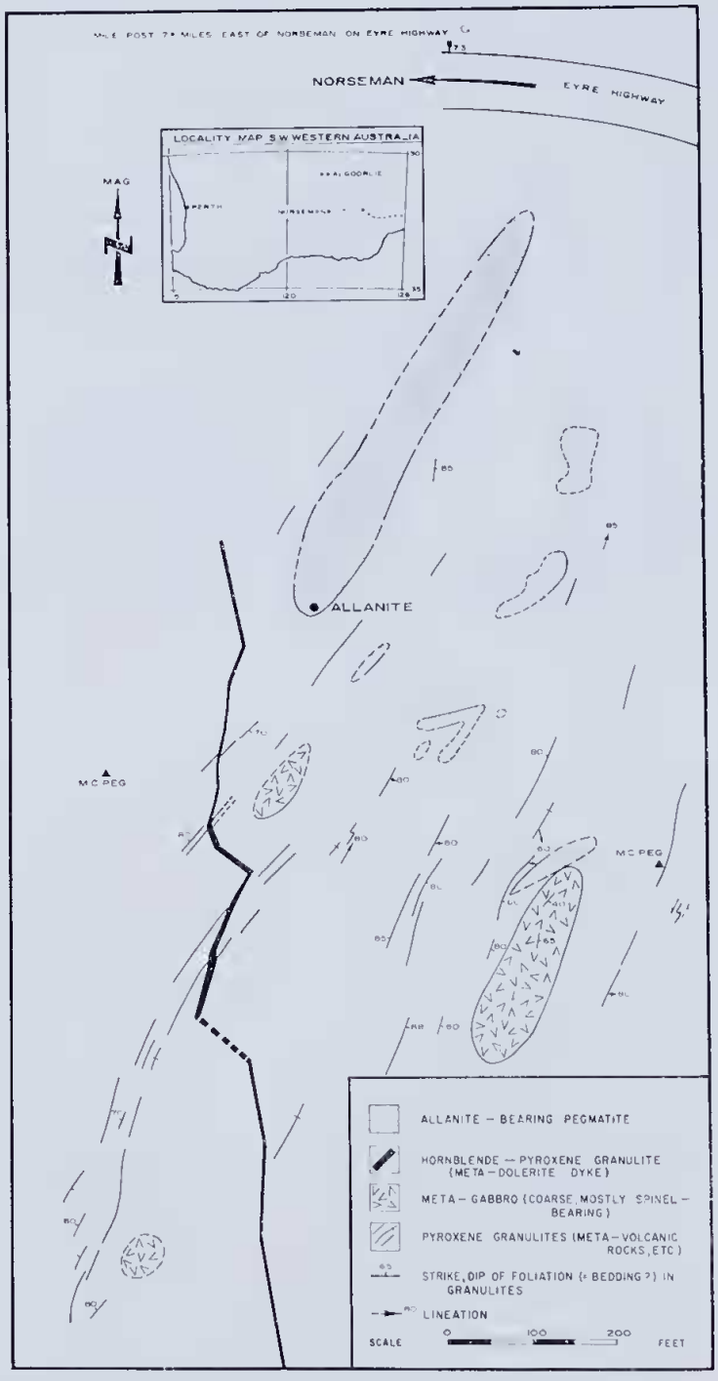

Fig. 1.

* University of Queensland, St. Lucia, Queensland.

A carefully handpicked sample of allanite was submitted to the Government Chemical Laboratories, Perth. Mr. J. N. A. Grace made a chemical analysis of the mineral. In addition, U, Th and Pb were determined on another portion of the original crystal. These results were originally required (in 1953) for an estimation of the age of the allanite.

Analyses of this allanite and of the other metamict allanite from the Fraser Range are set out in Table 1. The mean atomic weight of [La] was taken as 144, and of [Y] as 120 (following Hasegawa 1960 p. 352).

Hasegawa has shown from his exhaustive study (1960 p. 374) that allanite is a variety of epidote, $Ca_2(Fe^3Al)_3Si_3O_{12}(OH)$, in which a part of the Ca is replaced by rare earth atoms, and a part of Fe^3 or Al atoms by Fe^2. He points out that the replacement does not take place completely but is confined within narrow limits. Hasewaga gives the general formula and limits of composition, thus:—

$(Ca_{2-n}Ce_n)_2\ (Fe^2{}_nFe^3{}_{1-n})\ (Fe^3{}_mAl_{2-m})_2\ Si_3O_{12}(OH)$
where $1.00 > n > 0.60$, $0.45 > m > 0.05$, Ca = Ca + Mn, Ce = total rare earths and Th, Fe^2 = Fe^2 + Mg, and Al = Al + Be + Ti.

The chemical characteristics of the two allanites from the Fraser Range are very similar, and fall within the range of common allanites in most respects. However, MgO and Al_2O_3 are slightly more abundant than normal, whereas ThO_2 and H_2O+ are slightly low.

In 1952 an attempt was made to determine the age of the Fraser Range pegmatites. Allanite was first analysed for the normal constituents, and from a larger sample U, Th and Pb were determined. Moreover, an unsuccessful attempt was made to extract enough Pb for isotope analysis. From the normal analysis ThO_2 was given as 0.79 (i.e. Th = 0.69) whereas the data from the large sample was U = 0.06, Th = 0.87, Pb = 0.064.

TABLE 1

Allanite, 10 miles east of Fraser Range Homestead, Fraser Range, W.A.

Analyst: J. N. A. Grace 1953 (Gov. Chem. Lab. No. 6126/52).

Weight %		Atomic Proportions X10000		Atomic Ratios	
CaO	11.46	Ca	2044	1.12	
MnO	0.46	Mn	65	0.04	
ThO_2	0.79	Th	30	0.02	1.87
Ce_2O_3 / $[La]_2O_3$	20.67	[Ce]	1245	0.68	
$[Y]_2O_3$	0.17	Y	12	0.01	
FeO	8.44	Fe^{+2}	1175	0.64	
MgO	1.96	Mg	486	0.27	1.25
Fe_2O_3	4.93	Fe^{+3}	617	0.34	
Al_2O_3	17.20	Al	3374	1.84	2.27
TiO_2	0.63	Ti	79	0.43	
SiO_2	32.21	Si	5360	2.93	2.93
H_2O+	1.08	OH	1200	0.66	0.66
H_2O-	0.02	O	21979	12.00	12.00
	100.02				

n = 1.681 ± 0.001 ; S.G. = 3.40.

Formula (on the basis of twelve O) :

$(Ca_{1.12}Mn_{0.04}\ [Ce]_{0.68}\ [Y]_{0.01}\ Th_{0.02})_{1.87}\ (Fe^{+2}_{0.64}\ Mg_{0.27}\ Fe^{+3}_{0.34})_{1.25}\ (Al_{1.84}\ Ti_{0.43})_{2.27}\ Si_{2.93}\ O_{12.00}\ OH_{0.66}$

Using the values of U, Th and Pb an age of about 1210 x 10^6 years may be calculated. This compares remarkably favourably with the Rb/Sr and K/A ages (1280 x 10^6 and 1210 x 10^6, respectively) measured by Dr. W. Compston on muscovite (No. 41295) from the same pegmatite (Wilson *et al.* 1960, Table 1. No. 22).

The significance of the age of the allanite-bearing pegmatite is that it gives the minimum age of the charnockitic rocks of the Fraser Range. It is likely that the pegmatite was emplaced at the end of the grand phase of metamorphism which converted the country rocks to granulite facies. Thus the peak of the metamorphism is considered to be close in time to 1210 x 10^6 years ago. The structure and age relationship of the Fraser Range to the rest of the Shield may be seen from the map and text of earlier publications (Wilson 1958, pp.77, 80 etc.; Wilson *et al.* 1960 p.186; Wilson 1965).

TABLE 2

Allanite, Fraser Range, W.A. (Simpson 1948 p.30)

Weight %		Atomic Proportions X10000		Atomic Ratios	
CaO	11.91	Ca	2124	1.17	
Na_2O	0.01	Na	3	0.00	
K_2O	0.08	K	18	0.01	
MnO	0.55	Mn	78	0.04	
ThO_2	1.04	Th	39	0.02	1.89
Ce_2O_3	9.64	Ce	588	0.32	
$[La]_2O_3$	9.20	La	548	0.30	
$[Y]_2O_3$	0.45	Y	31	0.02	
Er_2O_3	0.19	Er	10	0.01	
FeO	8.26	Fe^{+2}	1150	0.63	
MgO	1.36	Mg	337	0.19	1.21
Fe_2O_3	5.73	Fe^{+3}	718	0.39	
Al_2O_3	17.48	Al	3429	1.88	1.90
TiO_2	0.24	Ti	30	0.02	
SiO_2	32.69	Si	5440	2.99	2.99
P_2O_5	0.02	P	3	0.00	
H_2O+	1.55	OH	1722	0.95	0.95
H_2O-	0.15	O	21834	12.00	12.00
	100.65				

n = 1.690 ; S.G. = 3.34

Formula (on the basis of twelve O) :

$(Ca_{1.17}\ K_{0.01}\ Mn_{0.01}\ Ce_{0.32}\ [La]_{0.30}\ (Y)_{0.02}\ Er_{0.01}\ Th_{0.02})_{1.89}\ (Fe^{+2}_{0.63}\ Mg_{0.19}\ Fe^{+3}_{0.39})_{1.21}\ (Al_{1.88}\ Ti_{0.02})_{1.90}\ Si_{2.99}\ O_{12.00}\ OH_{0.95}$

TABLE 3

Comparison of chemical composition of the two Fraser Range allanites and the general range of chemical variations of 126 allanites from elsewhere in the world (after Hasegawa, 1960).

	1 Wt. %	2 Wt. %	General range of world allanites (extremes excluded) Wt. %
CaO	11.46	11.91	6–13
MnO	0.46	0.55	0–7 (mostly 0–2)
ThO_2	0.79	1.04	Close to 1
Rare earths	20.84	19.48	19–27
FeO	8.44	8.26	5–14 (mostly 9–13)
MgO	1.96	1.36	0–1
Fe_2O_3	4.93	5.73	2–10
Al_2O_3	17.20	17.48	14–17
TiO_2	0.63	0.24	0– 1
SiO_2	32.21	32.69	30–34
P_2O_5	n.d.	0.02	< 1
H_2O+	1.08	1.55	1.5–2

1 = Allanite, 10 miles east of Fraser Range Homestead.
2 = Allanite, Fraser Range (Simpson 1948 p. 30).

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